SECTION 2

STRUCTURAL HULL

2.1 REFERENCES

(2A) Code of Federal Regulations – 46 CFR Sub-chapter H

(2B) Code of Federal Regulations – 46 CFR Sub-chapter S

(2C) SHIP STRUCTURE COMMITTEE-331, *Ship Structures Committee Design Guide for Ship Structural Details*

(2D) SNAME Publication, *Ship Design And Construction (1969 edition)*

(2E) ABS Rules for Building and Classing Steel Vessels

(2F) DET NORSKE VERITAS, *Guidelines For Accuracy (Steelwork)*

(2G) ABS Guide for Building and Classing Passenger Vessels

2.2 INTRODUCTION

This Section contains the Contractor Design and Provide general requirements for the structural hull, tanks, skegs, rudders and foundations. Supplemental requirements regarding specific tanks and foundations are contained in other Sections of the Technical Specification.

Hull structure shall be designed for service in the partially protected waters of Puget Sound. The Contractor's design must consider the possibility of impact with deadheads and the resulting loads.

Refer to Section 102 of the Technical Specification for structural vibration requirements.

For WSF Fleet-wide Standardization purposes, End No. 1 of the Vessel shall always be considered the bow, and this designation shall delineate port and starboard, fore and aft wherever they are addressed in the Technical Specification.

2.3 WORKMANSHIP

All workmanship shall meet the highest standards of quality consistent to ensure requisite integrity and strength, fair lines and smooth surfaces, proper fit and alignment, and minimized stress concentrations. Special attention shall be given to neatness for items exposed to general public view including structural brackets and clips. Temporary assembly clips and padeyes shall be removed and the attachment welds ground smooth. Assembly welds shall be neat in appearance with **all** slag and spatter removed.

The Contractor shall submit a Book of Construction Standards and Details to the WSF Representative within sixty (60) days after the start of the Phase III Detail Design Stage of the Work for review and approval. These construction standards shall comply with the requirements of this Technical Specification. Those areas not specifically addressed within this Technical Specification shall comply with the requirements of DET NORSKE VERITAS, *Guidelines For Accuracy (Steelwork)* and the American Welding Society (AWS), *Guide for Steel Hull Welding*.

2.4 GENERAL

The Vessel shall be a Contractor design using ABS Rules for Building and Classing Steel Vessels as general guidance. The Vessel will not be ABS classed or inspected, however review and comment of the Contractor's structural design by ABS ***is required*** and all ABS comments to the Contractor shall be provided to the WSF Representative. After ABS comment review by WSF, WSF shall designate those comments that shall be incorporated into the Contractor's design as base Work, and shall not be the basis for any additional cost/schedule to WSF. Hull structure shall be steel and approved by USCG as required by References (2A) and (2B).

In general, structure shall be designed to minimize steel weight while providing an efficient, light yet stiff hull that minimizes structure borne noise. Hull structure will be approved by WSF prior to submission to USCG.

The Vessel shall be designed without an inner bottom to maximize access, except under the EOS tank area.

ABS Rules for Building and Classing Steel Vessels do not include guidance for single bottom design or for service restrictions (non-ocean service). Alternate structural design methods shall be utilized, which may include first principles and/or Finite Element Analysis (FEA). The hull design shall include consideration for the partially protected waters in which the Vessel will operate.

All steel shall be new and of ABS Grade A or B in accordance with ABS Rules, unless otherwise noted. The Lower Vehicle Deck steel shall be ABS, HSLA 572-50 except where stainless steel is required by the Technical Specification. ABS certification shall be required and shall be submitted to the WSF Representative. In order to keep track of the certified steel, each plate and shape shall be marked with the certification number. This certification

number shall be kept visible on the unused portion of the plate or shape until used. Plates and shapes shall be wheelabrated or sandblasted to near white, SSPC SP-10 of Steel Structures Painting Council (SSPC), and coated with an approved weld through pre-construction primer prior to fabrication. Primer shall be compatible with the painting system required by Section 14 of the Technical Specification.

Where stainless steel is called out for deck plating, the plate shall be AISI Type 316L.

Steel castings shall be in substantial agreement with ASTM A27-6S, mild to medium strength carbon steel for general applications (Grade 60-30, Class 1) and shall be processed, heat treated, inspected and tested in accordance with ABS Rules.

Unless otherwise specified, the Contractor shall provide **all** required materials.

Plating shall be stored vertically if exposed to the weather, and in any position if stored within a weathertight storage shed.

The Vessel's structural hull and superstructure shall be of all welded construction.

All structural steel shall be no less than $^{3}/_{16}$ inch thick. This minimum thickness shall be increased as necessary to meet the design criteria of these Requirements and the requirements of the Authoritative Agencies. Steel plate and stiffeners shall also be increased in thickness beyond that otherwise required in areas where damage, wear, rusting (e.g.. under pumps), or excessive vibration may result.

The use of deck and shell doubler plates is prohibited, except in way of the anchor stowage. The use of sole plates is allowed. Deck doubler plates below sounding tubes and drains for anti erosion purposes will be allowed where specified.

Structural details shall conform to the principles and practices set forth in this Section and Reference (2C) (www.shipstructure.org). Structural details shall be selected or designed with the goal of avoiding fatigue cracking throughout the sixty (60) year service life of the Vessel.

Expansion joints **shall not** be used as a means to alleviate stresses in structure, except in way of catwalks between the amidships house top and the Navigation Bridge Decks.

NOTE: The Navigation Bridge Deck catwalk is at the extreme fiber and must be designed to move so that it does not create hard spots.

Care shall be taken to maintain alignment of members to ensure structural continuity.

Holes for windows shall be cut with a minimum radius of four (4) inches. Other openings in the side shell, tank tops, inner bottom and bulkheads shall be cut with a minimum radius of six (6) inches. Corner Radii adopted shall meet the requirements of Reference (2E).

Heavy insert plates with radiused corners shall be provided for all hull openings and penetrations, including but not limited to piping, transducers, and sea chests. The thickness

of heavy insert plates shall be a minimum of ⅛ inch greater than the largest of the surrounding plate thicknesses.

Openings in structure shall normally be cut using numerically controlled machinery. If an opening is cut by hand, the edges shall be ground smooth. No jagged edges shall be allowed.

Limber and vent holes of a radius as indicated in **TABLE 2-1** shall be provided in the structural members of all tanks and locations below the Lower Vehicle Deck that can accumulate liquids in sufficient number and location to assure proper draining and venting of tanks, machinery spaces, bilges. Limber holes shall also be provided in all voids.

TABLE 2-1

LIMBER / VENT HOLE SIZE

Shape web depth (in inches)	Radius	Remarks
<6	1½ inch	No less than 1½ inch unless not structurally feasible
≥6 - <10	2 inch	
≥10 - <15	4 inch	
>15	6 inch	

Painting shall be as specified in Section 14 of the Technical Specification.

For definition of "wet spaces", see the *GENERAL* Subsection in Section 3 of the Technical Specification.

NOTE: For the purposes of this Contract throughout the Technical Specification, Weather Decks and bulkheads are defined as all areas located on the inside of the Vehicle Deck Curtain Plate, Vehicle Deck and Ramp overheads (includes "tunnel" areas), Machinery Casing exteriors, interior of the Sun Deck Passenger Lounges, Passenger Deck embarkation areas vestibule overhead, Pilothouse visors, Pilothouse Bridge Wings, and any other areas exposed to the weather.

2.5 WELDING

All welders performing Work in or on the Vessel, and in or on components or structures intended for use or installation in or on the Vessel, shall be proficient and certified for the type of Work that they are, or may be, assigned to.

All welding, procedures, and welder qualifications and certifications shall satisfy the requirements of 46 CFR §57, including ASME BPVC, Section IX. Although the Vessel will not be ABS Classed, welds, weld procedures, and welder qualifications and certifications shall conform to the requirements of the ABS Rules for Building and Classing Steel Vessels wherever the requirements of 46 CFR §57 are not controlling.

The welding procedure, welder qualification, and welder certification requirements outlined in this Section of the Technical Specification are applicable to, and form a part of, every Section of the Technical Specification which may require the utilization of welding and welders.

Welders shall be certified through the performance of tests required by 46 CFR §57, ASME BPVC Section IX, or ABS tests Q1 through Q4, Table 2/3C.1, as applicable to the type of welding each individual will be performing.

No welder shall be assigned to a welding task aboard the Vessel, or to any structure or component being fabricated off the Vessel for future installation in or on the Vessel, until the WSF Representative has been provided a valid proof of current qualification.

Should any welder's certification expire, for whatever reason, at any time during the renovation period, that welder shall be immediately removed from the Work and shall not be re-employed on the Vessel, or its structure or components, until such time as re-certification is obtained and documented to the satisfaction of the WSF Representative or the appropriate Authoritative Agency.

The Contractor is wholly responsible for developing all welding procedures to be used during the performance of the Contract and for ensuring compliance with the requirements of ABS and other cognizant Authoritative Agencies.

All welding procedures shall be submitted to the WSF Representative for approval prior to their being used for any Work in or on the Vessel, or Contractor manufactured components or structures to be installed in or on the Vessel. Welds which have been made prior to procedure approval by the WSF Representative may be rejected in whole or part, or may be subject to the most stringent inspection methodology regardless of the location of the welds.

Welding symbols shown on any illustrative drawings are for informational and guidance purposes only. Welding symbols on Working Drawings shall conform to those adopted by the American Welding Society (AWS) as required by Section 100 of the Technical Specification. The use of symbols other than these will be cause for immediate rejection of the drawing(s).

Welding on the shell, decks, superstructure, and exposed interior bulkheads is to be performed in a sequence that will produce surfaces that are free of buckles, bulges and other surface irregularities. Welding that would cause burning or peeling of the outside hull paint below the waterline after the new underwater paint system has been applied **shall not** be undertaken without specific written approval of the WSF Representative.

Only continuous welding shall be permitted in potable water tanks, oily water holding tanks, bilges, toilet spaces, shower spaces, cleaning gear lockers, stairways from the Lower Vehicle Deck to the Passenger Deck, food preparation and vending areas, sanitary spaces and/or other spaces where it could result in corrosion to the weld ends or edges of attached members.

Plate edge preparation and fitting shall be in accordance with ABS Rules, or the requirements of DET NORSKE VERITAS, whichever is more stringent.

All Upper and Lower Vehicle Deck stiffeners in way of vehicle lanes, including ordinary transverse or longitudinal beams, deep transverse beams, and longitudinal girders, generally shall be staggered intermittent welds that comply with ABS rules.

Welding in adverse weather conditions may be performed with the specific approval of the WSF Representative where adequate precautions necessary to ensure weld quality are observed.

Weld sequence procedures shall be designed to minimize distortion and shall be submitted to the WSF Representative for approval. No welding shall be done without approved weld sequencing procedures. Weld sequencing procedures and submittals shall be provided the same status as a system test, and all the requirements, procedure formats of Section 101 of the Technical and Shipyard Specifications shall apply.

2.6 INSPECTION

Welds shall be inspected as necessary to satisfy cognizant Authoritative Agencies and the WSF Representative. Radiographic Inspection or other appropriate inspection techniques shall be performed by Certified individuals, independent of the Contractor as may be required by a cognizant Authoritative agency inspector or the WSF Representative. The results of all inspections shall be presented in written reports within 24 hours of the test to both the requesting agency and to the WSF Representative regardless of which entity or empowered individual requested the inspection.

Prior to testing, the Contractor shall develop a Radiographic Testing Plan, which shall comply with the ABS Rules for Nondestructive Inspection of Hull Welds, Section 2.

The minimum extent and location of Radiographic Inspection shall meet the requirements of Section 2, Articles 2.3 and 2.4 of ABS Rules for Nondestructive Inspection of Hull Welds. All NDT inspection methods and interpretation shall comply with ABS Rules. The word "Surveyor" as used in the ABS documents shall be synonymous with WSF Representative.

The Contractor shall identify each location to be radiographically inspected on a construction drawing which shall be submitted to the WSF Representative prior to the commencement of any welding. The WSF Representative may relocate a portion of the designated radiographs after welding is complete. The Contractor should assume that 33-percent (33%) of the total number of radiographs designated on the testing plan, may be relocated by the WSF Representative at no cost or schedule change to the Contract. WSF will take possession of all radiographic film for each Vessel after hull construction is complete.

The WSF Representative may require additional inspections, including inspections more stringent than those originally employed, to prove the quality and integrity of any weld at any time there is reason to question the weld because of its appearance or the conditions under which the weld was performed. The WSF Representative may order additional testing on a random basis. If the results of inspections requested by the WSF Representative prove that the weld is sound, the Contractor will be compensated for the testing Work at the Time and Materials, Force Account, basis in accordance with the Contract.

Should the testing reveal a defective weld, the testing and repair shall be wholly at the Contractor's expense. At any time that non-destructive testing reveals a defective weld, the testing shall be expanded at the Contractor's expense until a sound weld is located. All defective welds shall be removed and renewed to the satisfaction of the WSF Representative and the cognizant Authoritative Agency Inspector. The Contractor shall be wholly responsible for all expenses associated with the removal and replacement of defective welds.

2.7 INTEGRITY

Shell plating, watertight bulkheads and the Lower Vehicle Deck shall be watertight.

Watertight integrity shall meet the requirements of 46 CFR §72 and §171.

2.8 FAIRNESS CRITERIA

The following **TABLE 2-2** gives the maximum acceptable depth of unfairness of newly installed plating between frames, stiffeners, or deck beams. Depth of unfairness is measured by placing a straight edge three (3) times the frame, stiffener, or beam spacing in length, across the plating between frames, stiffeners, or deck beams. The depth of the maximum allowed hump or hollow is then measured from the straight edge thus applied.

TABLE 2-2

FAIRNESS CRITERIA

	MISC. BHDS, DK HOUSE SIDES & TOPS, MISC. FLATS, & FUNNEL				ALL SHELL PLATING, INCLUDING F. P.K. & GUARD, CURTAIN PLATING, VEHICLE, PASSENGER & SUN DECKS & MAIN BHDS				
STIFF. SPAC'G	7.65 lb. (3/16")	10.2 lb. (1/4")	12.75lb (5/16")	15.3 lb. (3/8")	7.65 lb. (3/16")	10.2 lb. (1/4")	12.75lb (5/16")	15.3 lb. (3/8")	20.4 lb (1/2")
28"	3/8"	3/8"	3/8"	5/16"	5/16"	5/16"	5/16"	5/16"	5/16"
27"	3/8"	3/8"	3/8"	5/16"	5/16"	5/16"	5/16"	5/16"	5/16"
26"	3/8"	3/8"	5/16"	5/16"	5/16"	5/16"	5/16"	5/16"	5/16"
24"	5/16"	5/16"	5/16"	1/4"	5/16"	5/16"	5/16"	5/16"	1/4"
22"	5/16"	5/16"	1/4"	1/4"	5/16"	5/16"	1/4"	1/4"	-
20"	5/16"	1/4"	1/4"	3/16"	1/4"	1/4"	1/4"	3/16"	-
18"	1/4"	1/4"	3/16"	3/16"	1/4"	3/16"	3/16"	3/16"	-
14	3/16"	3/16"	3/16"	-	3/16"	3/16"	3/16"	-	-
13.5"	3/16"	3/16"	3/16"	-	3/16"	3/16"	3/16"	-	-

During deck plating installation, or other structural Work, the Contractor shall exercise great care to assure that surfaces are free from "oil can" (unstable plate) deflection. Should "oil can" deflection occur, the Contractor shall remove the deflection by heat shrinking or mechanical displacement. Additional stiffening is prohibited without written WSF Representative approval.

NOTE: See the weather deck drain "pooling" area requirements in the *Weather Deck Drains* Subsection in Section 11 of the Technical Specification.

Where preventive measures are insufficient to control distortion and fairness tolerances are exceeded, straightening shall be employed to the minimum extent necessary to bring the plating within the tolerances specified.

Flame straightening may be used for all hull structural applications involving steel plate in the "as-rolled" or normalized condition. The use of filler products to fair bulkheads and decks **will not** be permitted.

2.9 BEAM STRAIGHTNESS CRITERIA

Frame, beam and stiffener bows in all structure shall be corrected when it varies plus or minus from the designed or molded line in excess of $^{3}/_{8}$ inch or the following, whichever is less:

$$\frac{\text{Span (feet)}}{\text{Depth (inches)} \times 4} = \text{Tolerances (inches)}$$

Span is the distance between the fixed ends at support structure, and Depth is the depth of a stiffening member measured from the underside of the flange. The measurement shall be taken from the most distorted position of the web.

2.10 ALIGNMENT CRITERIA

Structural components shall be aligned according to the following ASTM F1053/F1053M criteria:

2.10.1 Alignment Criteria (Intercostal Structure)

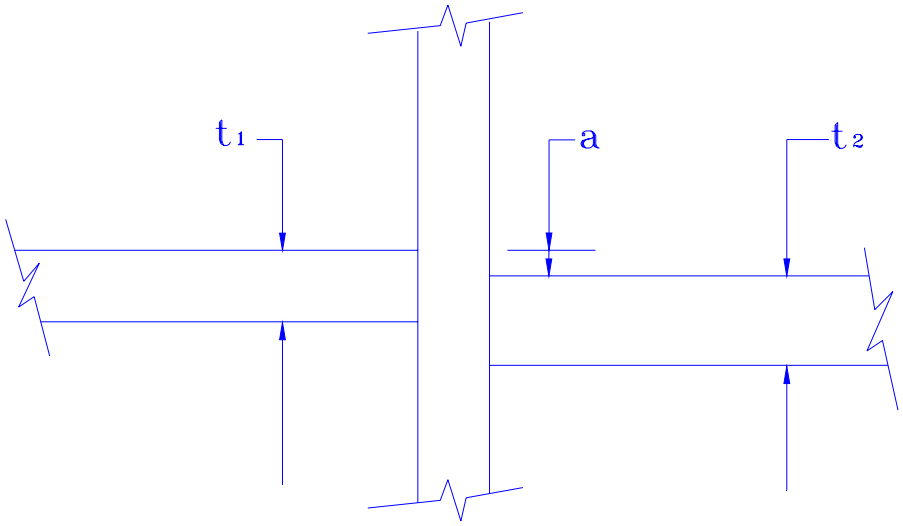

FIGURE 2-1

Intercostal Structure

a = allowable offset t = thickness $t_1 \leq t_2$

For principal longitudinal strength members:

$$a \leq 1/3\ t_1$$

For other structural members:

$$a \leq 1/2\ t_1$$

The alignment criteria applies to all structural alignments except butt joints including but not limited to: brackets; alignment of intercostal stiffeners, beams and girders; bulkheads, stanchions and pillars above or below a deck, or on opposite sides of a bulkhead, or the web of a beam or girder. Pipe stanchions of different diameter, and stanchions constructed from "I" or "H" sections, will be given special consideration.

2.10.2 Alignment Criteria (Butt Joints)

Every effort should be made in assembly of structure to obtain 100-percent (100%) alignment on the molded line side of the members being joined as shown below:

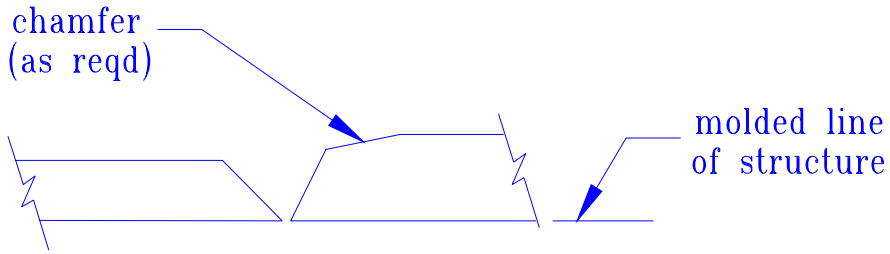

FIGURE 2-2

Molded Butt Joints

The maximum allowable offset tolerance shall be 15-percent (15%) of the thickness of the thinner member being joined (ASTM F1053 criteria), as shown below:

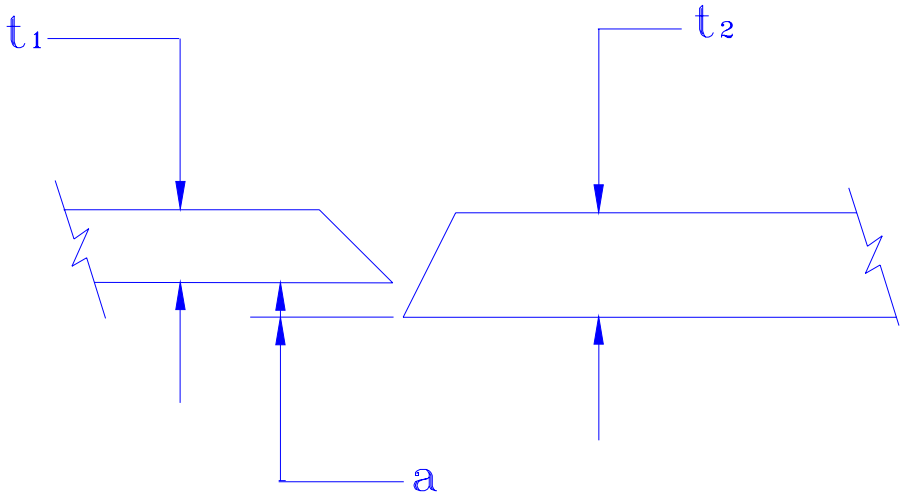

FIGURE 2-3

Offset Butt Joints

a = allowable offset $\leq (0.15)\, t_1$ t = thickness $t_1 \leq t_2$

2.11 PENETRATIONS OF STRUCTURAL MEMBERS

Penetrations of structural members (beams, bulkheads, girders, decks, etc.) for piping, ducting, or otherwise shall be kept to an absolute minimum and compensated for, if required.

For penetrations of structural members for piping, wiring, or vent ducts, suitable compensation shall be fitted as necessary to maintain strength. If a structural member has to be penetrated, the construction drawings shall depict the penetration with a detail of the penetration including cut size, location, and strengthening in way of the cut, if required. Location of penetrations and openings in structure, and associated stress concentration relief, shall be guided by Chapter V, Section 18, Figure 54(a) and subsections 18.8 and 18.9 of the SNAME publication - *Ship Design And Construction (1969 edition),* Reference (2D). For penetrations and openings which do not conform to the above, calculations of the strength of the penetrated member shall accompany the drawing and compensation shall be provided with guidance from Chapter V, Section 18, subsection 18.10 of Reference (2D).

Penetrations and all strengthening shall be the responsibility of the Contractor.

Through bolts with nuts and washers shall be used in lieu of drilled and tapped holes through structure.

2.12 SHELL PLATING AND STEM

The arrangement and thickness of plating shall be determined by the Contractor's design. Seams and butts forming the boundaries of differing plate thickness shall be determined by the Contractor's design. Seams and butts within areas of the same thickness may be located to suit the Contractor's standard practice, subject to approval of the Authoritative Agencies and the WSF Representative. All shell openings and penetrations shall be compensated with heavy insert plates with radiused corners. Doubler plates **shall not** be used.

The plate guard (rub rail) shall have sharp edges chamfered off to a generous radius and ground smooth to prevent damage to ferry slips.

The stem bar connection to the shell plating shall be fair, well-rounded and welds ground smooth.

2.13 HULL FRAMING

Hull framing, spacing and scantlings shall be determined by the Contractor's design and this Technical Specification.

2.14 DECKS ~ DECK SCANTLINGS, CAMBER, AND SHEER

Deck scantlings shall be determined by the Contractor's design, with an added thickness margin for the Lower Vehicle Deck of $^{1}/_{16}$ inch for corrosion over the Vessel's service life, except that the thickness of the Lower Vehicle Deck **shall not** be less than ⅜" plate (ASTM A 572 (50 ksi) inboard of the casings and knuckles, and ⅝" plate (ASTM A 572 (50 ksi) outboard of the casings.

Lower Vehicle Deck transverse stiffeners shall be WT 6×11# inboard of 15'-9" off centerline. Stiffeners on frames shall be continuous in way of casings, and the like. Stiffeners on half frames may be discontinuous if properly headed, but shall extend under all Vehicle lanes.

Stiffeners shall be welded to the deck plates with minimum $^{3}/_{16}$ inch (0.188") full penetration, staggered intermittent welds, 2½" long on 6 inch centers. Double continuous welds, of equal strength, may be allowed after successful demonstration and approval by the WSF Representative, during the Phase II design development phase of this Contract, that such a method can be accomplished without "washboarding" of the plate. "Washboarding" is defined for this Contact as similar to what exists on the WSF Jumbo Mark II Class Vessels, and **shall not** be acceptable. The determination of the WSF Representative shall be **FINAL** as to this issue.

The reverse shear at edges shall be ½" Type 316L stainless steel.

Deck thickness at the Ends shall be ½" mild steel for approximately 26 feet from the reverse sheer.

Decks shall be suitably reinforced with heavy insert plates, headers, additional stiffening, etc., as necessary in way of deck machinery, mooring fittings, masts, openings, penetrations, etc. No doubler plates shall be fitted.

Weather deck camber and sheer shall be as required by the *Camber and Sheer* Subsection in Section 1B of the Technical Specification. No deck camber or sheer shall be allowed within any interior spaces.

Weather decks and all interior steel decks, coamings, and deck connections of steel bulkheads, in way of toilets, washrooms, cleaning gear lockers, showers, scullery and refrigerated spaces shall be proven tight prior to application of any deck or bulkhead covering and after all preparatory work involving water tightness has been completed. See Section 101 of the Technical Specification.

2.15 DECK GIRDERS

Girders shall be installed as determined by the Contractor's design to adequately support and distribute loads indicated during the development of the design and the course of construction. Provide all necessary chocks and brackets.

2.16 PILLARS AND STANCHIONS

Pillars and stanchions shall be designed and provided to adequately support and transmit the imposed loads. Where additional pillars or stanchions appear necessary as the design develops, their location shall not interfere with the function of the Vessel and shall be subject to approval by the WSF Representative. Pillars shall be of steel seamless pipe or tubing, or

structural tubing; and shall land on adequate strength members. Provide all necessary cap plates, bearing plates, chocks, etc. Electric resistance welded pipe **will not** be allowed.

2.17 BULKHEADS

Bulkhead scantlings shall be as determined by the Contractor's design. Bulkheads shall be provided with continuity and of the tightness indicated. Special attention shall be given to bulkheads in way of loads imposed by girders, etc., and provide all necessary brackets, etc.

Swash bulkheads shall be fitted as indicated or as necessary to minimize the dynamic effects of free moving liquid on the tank boundary structure.

BE ADVISED: ***A watertight double bottom space shall be formed in way of the EOS, Engineer's Dayroom, Engineer's Restroom, and Workshop Areas between the midship Engine Room bulkheads, End No. 1 and No. 2. The double bottom space shall be bounded by the hull and the bottom of the fuel tanks and the shaft tunnel, the longitudinal girder approximately 28' -3" off Centerline port and starboard, the deck at the EOS level between port and starboard, and the sides of the Fuel Oil Storage Tanks port and starboard.***

2.18 TRUNKS

The positions and scantlings of trunks shall be provided by the Contractor's design. Where trunks such as escape, access, elevators, etc., pierce decks, the deck cuts are to have adequately radiused corners. The minimum size of access trunks shall be 30 inches × 30 inches.

For additional information concerning the Elevators, see Section 23 of the Technical Specification.

2.19 FOUNDATIONS AND BOLT-DOWN FITTINGS

2.19.1 General

Foundation requirements for commissary equipment are covered in Section 17 of the Technical Specification. Refer to Section 70 of the Technical Specification for foundation coaming requirements.

2.19.2 Items Requiring Foundations

All equipment weighing 150 pounds or more shall be supported by foundations. Items weighing less than 150 pounds shall be supported by foundations or bracket assemblies, as approved by the WSF Representative for each installation. Foundations Calculations

shall be provided for **all** foundations supporting equipment. Calculations shall be provided with the associated drawing as set forth in the *REVIEW OF DRAWINGS AND ENGINEERING CALCULATIONS* Subsection in Section 100 of the Technical Specification.

Foundations for machinery and equipment shall meet the following criteria:

1. Have strength and stiffness required to support and maintain alignment of mounted equipment in its operating mode.

2. Loadings to be considered in the design of foundations shall include:

    a. Dry weight of equipment.

    b. Weight of fluids.

    c. Dynamic loadings induced by equipment in operation.

    d. Weights of ancillary components and systems, piping, wiring, etc.

    e. Vessel motion.

3. Distribute machinery and equipment loadings to the Vessel's primary structure. Provide additional structural members like headers and chocks as required.

4. Provide for alignment and other special requirements of the mounted machinery.

5. Provide access to all parts of equipment for inspection and maintenance, and access for maintenance to foundations and adjacent hull structures. Pockets and inaccessible places, where corrosion cannot be controlled or where dirt and debris can accumulate, shall be avoided. Foundations exposed to weather using closed box foundations (see the *Requirements Specific to Equipment Exposed to Weather* Subsection below) shall be provided with bolted, watertight accesses.

6. Main Propulsion equipment foundations shall be double continuously welded as required by ABS Rules.

Where machinery, such as a pump with motor, is supplied bolted to a substantial steel base, the base may be welded to the foundation, provided the machinery (including future replacements) can be aligned after welding the base and foundation together.

Foundations for machinery containing liquids shall have coamings of dimensions and construction as specified in the particular Sections of the Technical Specification in order to contain any leakage. Each coamed area shall be provided with at least one (1) valved drain connection provided in accordance with the requirements of Section 74 of the Technical Specification.

Foundations for the Main Engines and Reduction Gears shall be fitted as integral parts of the Vessel's primary structure. Abrupt discontinuities shall be avoided by gradual tapers at extremities of foundation structure. These foundations shall be integrated into the primary longitudinal Vessel structure in a manner which ensures structural continuity and mitigates stress concentrations. Other foundations in Engine Rooms shall be similar in character, attention being given to rigidity of the foundation proper. All necessary tripping brackets, chocks and additional stiffening shall be developed by the Contractor.

The rigidity of foundations and supporting structure shall be sufficient to prevent misalignment which would interfere with operation of the equipment and to preclude excessive vibratory motion or rocking on the foundation.

Foundations subject to cyclic or reversed loading shall be designed to withstand fatigue associated with a minimum sixty (60) year service life.

Piping connections to equipment **shall not** be considered as reducing the load to be supported by foundations.

In cases where insert plates are required to increase the section modulus of structural members in way of foundations, the extent of the insert shall be based on the design structural loading and moment distribution, but in no case shall the extent be less than twelve (12) inches past the point of maximum moment in the direction of loading.

The foundation structure shall be arranged so that, under dynamic conditions, loading is distributed equally among all equipment securing fasteners.

2.19.3 Vibration

Foundations shall be designed with due regard to the vibration and noise requirements of Section 102 of the Technical Specification. Foundations for antennas shall be such that natural resonant frequencies will not interfere with the operation and effectiveness of the antennas.

2.19.4 Attachment to Structure

Foundations shall be made from steel plate and shapes, welded together, and to the Vessel's structure.

Foundations shall be attached to primary structure, which shall be stiffened where necessary to carry both static and dynamic loads.

Continuity of structure shall be provided so that loads are properly distributed into hull structure of adequate strength and rigidity.

To minimize weight, structural members of the hull may be used as parts of foundations wherever practicable, provided they are reinforced as necessary to carry the additional loads.

Equipment shall be supported **without** direct connection to the shell or other structure subject to wave impact, contact with waves, propeller excited vibrations or similar loading, where the distortion or vibration would damage the equipment or impair its performance.

Equipment **shall not** be rigidly attached to two (2) structures that can deflect relative to each other under dynamic loading.

2.19.5 Drainage

Limber and lightening holes shall be used wherever the required strength and rigidity are not adversely affected. See the *GENERAL* Subsection in this Section of the Technical Specification.

Complete drainage of foundation structure shall be provided. Drainage in way of foundation coamings and drip trays shall be provided as required in Section 70 of the Technical Specification.

2.19.6 Alignment

In each case where two (2) or more equipment components require permanent and accurate alignment, fitted bolts, fitted tapered pins, or other means shall be provided to maintain alignment and ensure proper realignment after removal for maintenance.

Foundations shall be designed in a manner which precludes damaging misalignment or strain caused by thermal expansion.

Top sway braces shall be installed in any case in which equipment is not designed for environmental loads and the ratio of height to the base dimension of the mounted item is three (3) or greater. Where this ratio is less than three (3), sway braces shall be provided if necessary to ensure proper bracing of the item. Braces shall not restrain equipment vertically.

2.19.7 Attachment of Equipment to Foundations

Chocking material, blocks, resilient mounts, gaskets, fasteners and other material shall be provided, as required, to attach equipment to foundations.

Threaded fasteners used to fasten equipment to foundations shall include positive locking of the nut. The use of lock washers is prohibited. Unless impractical, nuts with nylon inserts shall be used.

The attachment of equipment to foundations shall provide for relative movement caused by thermal expansion.

In the assembly of equipment subjected to large reversing stresses such as thrust bearings and steering gear components, fitted bolts, keys or dowel pins shall be used to withstand the forces tending to shift the unit on its foundation.

Engines, Reduction Gears, generators and auxiliary equipment (such as windlasses, winches and capstans) which exert heavy loading on foundations shall be secured by means of fitted bolts and self-locking nuts.

Bolts, studs and cap-nuts used to fasten aluminum components shall be of Type 304 stainless steel. Threads shall be coated with appropriate anti-seize lubricant. All stainless steel fastener threads, without exception, shall be coated with appropriate anti-seize lubricant.

2.19.8 Requirements Specific to Large Equipment

Large equipment which must be aligned with connected equipment shall be installed on metal or cast resin chocks. Any such equipment mounted on resilient mounts must adequately compensate for relative equipment motions.

The foundations of the following equipment shall be consistent with the recommendations of the equipment manufacturer with regard to optimum installation in addition to meeting the minimum requirements:

A. Propulsion Diesel Engines (Main Engines)
B. Reduction Gears
C. Ship's Service Diesel Generators
D. Emergency Diesel Generator and Remote Radiator
E. Marine Evacuation Slides (MES), and Rescue Boat Davits
F. Anchor Winch
G. High Speed Shaft
H. Line Shaft Bearings

2.19.9 Requirements Specific to Equipment Exposed to Weather

All equipment exposed to the weather shall make use of closed box foundations. The outside periphery of the box shall be flush with the base outline of the equipment so as to present a smooth, easy-to-maintain structure. Where high loads or safety make the use of studs impractical, flanges may be added to the closed sections to allow the use of other attachments suitable for the intended service.

2.20 SKEGS

Welding of the skeg and hull plates shall be continuous.

2.21 STERN FRAME AND RUDDER HORN

The stern frames and rudder horns shall be cast steel or fabricated to suit the Contractor's design and shall be in accordance with ABS Rules.

They shall be fair to the hull structure and rabbeted for flush attachment to the shell plating. All exterior welds are to be ground smooth to prevent turbulence and erosion.

Welding of stern frame to rudder horn shall be in accordance with ABS Rules.

The stern frame bearing boss shall have provisions for attachment of the stern tube. The stern tube may be of cast steel, heavy wall-thickness pipe or rolled plate weldment. Stern tubes are to be continuous through the peak bulkhead and shall be welded to the bearing boss and inboard seal casting (or forging). Connections to intermediate framing shall be by welded collars. Alternative methods of securing the stern tubes to suit the Contractor's production methods and facilities will be acceptable, subject to approval of the WSF Representative and the USCG.

The Contractor shall request, in writing, WSF approval for weld repair of castings.

2.22 HIGH PERFORMANCE FLAP TYPE RUDDERS

Two (2) high performance flap type rudders, one (1) each end, ROLLS-ROYCE Marine AS High Lift Flap, or equal, sized and fit to the Contractor's design, shall be provided. The rudder and Steering Gear assembly shall be generally in accordance with ROLLS-ROYCE Drawing No. UN3288A.

Each high performance flap type rudder shall be provided mated to a single rotary type rudder actuator in each Steering Gear Room. See Section 81 of the Technical Specification.

2.22.1 General

Excepting the electrical cables and some interconnecting piping necessary for hydraulic oil transfer between the hydraulic oil reservoir and fixed storage tank, installation connections, and alarm annunciators and indicators in the Pilothouses and EOS Control Consoles; the Steering Gear, steering gear pedestal, rudder, rudder stock, rudder trunk assembly (complete with lower bronze rudder stock bearing, jump collar, seals, rudder flap linkage anchor, rudder guard, and steering control/monitoring systems) shall be purchased as a package from one (1) vendor, with all components fabricated, assembled, painted, pre-wired and tested by the manufacturer, ready for installation by the Shipyard.

The same steering system vendor shall have a service facility and field representatives in the Puget Sound area on a permanent basis for service and parts.

The Contractor shall submit stress diagrams and other incidental calculations when submitting the rudder assemblies for approval. The rudder assemblies shall be designed to withstand the conditions of speed and helm angle required for the Steering Gear specified in Section 81 of the Technical Specification. The rudder stock shall be hydraulic taper coupled to the rudder. Rudder stock material shall be ABS, GR 2 forging and shall be sized to suit the Contractor's design.

Flush welded access plates shall be provided on both sides of each rudder in way of the rudder stock nut. As an alternate, the access plates can be bolted in place with Monel socket head cap screws fitted into counter-bored holes in the plate, if it can be demonstrated these access plates will not carry away in service and can easily be removed on the dry-dock.

All exterior welding of the rudder assembly shall be ground smooth to prevent erosion due to turbulence. The rudder and flaps shall be watertight and their interiors shall be preserved in a method acceptable to the WSF Representative. Flush docking plugs of Monel shall be provided for the rudders and rudder flaps to provide for venting, complete drainage when in dry-dock, coating and testing the interior of the rudders. All plugs shall be provided in the same size to eliminate the need for various size wrenches. Two (2) wrenches shall be supplied to the Vessel matched to the size of the plug socket.

Rudder assemblies shall be provided with lifting holes. It is the intent of this paragraph that it shall be possible to ship and unship the rudders without the need to weld on and scarf off padeyes on the rudder skin. See Section 50 of the Technical Specification for design and testing requirements.

See Sections 81 and 94 of the Technical Specification for steering gear and control system requirements.

Recessed padeyes shall be installed on the Vessel's structure to provide means for ready rigging and positioning of the rudders as set forth in Section 5 of the Technical Specification.

Provisions shall be made for clearances necessary to permit the rudder to be shipped and unshipped with the stock detached.

The lowest point of the rudder assemblies shall be no less than six (6) inches above the baseline of the Vessel (bottom of the keel). The rudders and stocks shall be removable over the dry-dock floor when the Vessel is docked on blocks no higher than forty-eight (48) inches.

The rudder assemblies shall be provided with bolt-on zinc anodes as set forth in Section 14 of the Technical Specification.

See the *SHELL PLATE, RUDDER, AND FUNNEL MARKINGS* Subsection in Section 24 of the Technical Specification for welded number requirements.

WSF desires to witness that an inadvertent bow rudder "full-over" condition while underway will not damage the rudder system nor the Vessel. As the last item of Sea Trials, the Contractor shall perform a bow rudder "full-over" demonstration while underway at three (3) different speeds as set forth in the *SEA TRIALS* Subsection in Section 101 of the Technical Specification.

2.22.2 Required Characteristics

2.22.2.1 Rudder

1. The rudders shall be custom designed and hydro-dynamically high performance rudders, flap type, adapted to the Contractor's hull, and the OFE propeller (see Section 53 of the Technical Specification).

2. Welded construction of certified steel with drain plugs of Monel to resist thread galling and corrosion.

3. Cast steel rudderstock carrier for added strength.

4. Intermediate flap shaft bearing installed for added rigidity.

5. Rudder interior treated to resist corrosion.

6. Capable of achieving at any rudder angle by the rudder at one End of the Vessel at least 176,000 lbs. of bollard lateral thrust at 95-percent (95%) of maximum continuous rating (MCR) for the Main Propulsion Engines (5,700 BHP) and at least 92,000 lbs. at 50% MCR (3,000 BHP).

7. It shall be demonstrated, by evidence of operators of an existing double-ended ferry of similar size, weight, and service speed, that there is no rudder flutter condition experienced on either bow or stern rudder in either direction of travel for a maintenance interval of at least seven (7) years.

8. The rudder flap linkage shall be fixed to the flap by means of expansion rings (RINGFEDER keyless shaft hub connections, or equal) to avoid damage to the flap linkage. The linkage pivot points shall be stainless steel against spherical DEWA metal bearings that are seawater lubricated and can withstand horizontal movement of the rudder. It shall be readily possible to replace and/or adjust any part of the flap linkage assembly, if necessary, without dry-docking the Vessel.

2.22.2.2 Rudderstock and Related Assemblies

1. The Rudderstock shall not come in contact with seawater in normal operation.

2. The lower end of the rudderstock shall be tapered to fit in the mated tapered bore of the cast steel carrier which is integral with the rudder.

3. Rudder removal from the rudderstock shall be by means of hydraulic expansion of the rudderstock bore in the rudder carrier, and reinstalled by means of expansion of the rudder carrier bore combined with draw-up of a hydraulic nut screwed to the bottom end of the rudderstock.

4. The rudder (complete with flap and linkage assembly), rudderstock, rudderstock trunk (horn), rudderstock trunk lower bearing, rudderstock sealing system, and steering gear pedestal mount shall be custom-designed and fabricated by the high-performance rudder manufacturer as a complete system, and be delivered to the Shipyard ready to be welded into the Ends of the Vessel by Shipyard personnel.

5. The rudderstock trunk cavity shall be kept full of grease by means of a rudder manufacturer-supplied automatic lubricator located in each Steering Gear Room at the top of the trunk.

6. Rudderstock grease shall be confined in the space between the trunk cavity and the rudderstock. Seawater shall be prevented from entering the trunk cavity by means of a double-lip seal (the upper lip pointing up and the lower lip pointing down) installed at the bottom of the trunk in a seal retainer and jump collar assembly. The lip seal wearing surfaces shall ride on a renewable bronze liner, which is flanged on its lower end, fitted with an o-ring seal, and bolted to the top of the rudder around the diameter of the rudderstock.

7. There are no keyways cut in the rudderstock. The rudderstock shall be held in alignment with the rudder by the clamping force of a hydraulic draw-up procedure. The rudderstock is further held in alignment with the Steering Gear rotor by means of a hydraulic shrink connection.

8. The rudderstock shall be cylindrical where it passes through the rotary element of the rotary vane steering gear (See Section 81 of the Technical Specification). This constant diameter shall allow for either a rudderstock or steering unit replacement without machining or without the need to blue in the contact fit. Such design shall also makes height adjustment possible.

2.22.2.3 Rudder Trunk (Horn)

1. Designed and fabricated with steel shapes by the rudder manufacturer to fit into and conform to the shape of the Ends of the Vessel.

2. The lower end of the trunk shall contain a grease-lubricated bronze rudderstock bearing, properly sized to withstand the expected radial forces.

3. A jump collar shall be fitted at the lower end of the trunk to prevent upward movement of the rudder in case of contact with the sea floor.

4. Integral with the upper end of the trunk shall be a steel plate that welds to the Vessel's framing in each Steering Gear Room and also forms the platform on which to mount the Steering Gear foundation.

5. Equipped with a rudder guard (log splitter) of at least 1 inch thick steel plate that extends approximately eighteen (18) inches below the top surface of the rudder on the trailing edge. The purpose of the guard is to protect the rudder flap from striking floating debris when that rudder is on the bow end of the Vessel during transiting. The rudder guard is further fitted with an approximately 3½ inch diameter hole and certified as an 11,000 lb. capacity padeye to aid in removing or installing the rudder, propeller, or tailshaft while on dry-dock. See Section 5 of the Technical Specification for log splitter padeye requirements.

2.23 TESTS, TRIALS, AND INSPECTIONS

Tests and/or trials shall be in accordance with Section 101 of the Technical Specification.

Inspections shall be performed as defined in this Section and in Section 1 of the Technical Specification.

2.24 PHASE II TECHNICAL PROPOSAL REQUIREMENTS

The following drawings, analyses, and calculations, in addition to others required by Section 100 of the Technical Specification and the Authoritative Agencies, shall be submitted during the Phase II Technical Proposal stage of Work in accordance with the requirements of Section 100 of the Technical Specification:

A. Preliminary Scantling Calculations

B. Longitudinal Strength Analysis, Main Deck and Below

C. Lower Vehicle Deck Structure Analysis

D. Bow & Stern Structure Analysis

E. Preliminary Rudder Design Report

Scantling Plans shall include all decks, flats, platforms, bulkheads & stiffeners, major cutouts and compensation including windows.

Scantling Calculations for typical structure shall be provided in accordance with the following minimum design requirements matrix. Justification of other design pressures and analysis methods must be submitted to the WSF Representative for approval during the Phase II Technical Proposal stage.

Scantling	Design Pressure	Notes/Reference (Optional)
Bottom Shell Plating	Varies	ABS / Inboard of 15'-9" off CL
Side Shell Plating	Varies	ABS / Outboard of 15'-9" off CL
Bottom Transverse Frames	Varies	ABS (both as bottom & side frames)
Bottom Girders	Varies	First principles / DnV service restriction R3
Tank Boundary Bulkheads	Varies	ABS
Watertight Bulkheads	Varies	ABS
Lower Vehicle Deck	407 psf *	ABS / direct calculations

* Concentrated vehicle loads & associate calculations shall also be provided as set forth in the ***Vehicle Deck Structure Analysis*** below.

The scantlings and racking strength shall be confirmed by Finite Element Analysis (FEA).

FEA shall also be performed to demonstrate adequacy of structural scantlings supporting the main masts; and Passenger Deck both forward, aft, inboard, and outboard of the Machinery Casings.

Longitudinal Strength Analysis - The longitudinal strength of the Vessel is subject to special consideration due to its unusual proportions and form. A comprehensive Longitudinal Strength Analysis shall be performed, including still water and wave-induced bending moment analyses. The hull section properties shall be determined at intervals along the Vessel's length. Hogging and sagging conditions shall be examined for ABS-defined bending moments and for bending moments resulting from a trochoidal wave with a length equal to the length between perpendiculars (LBP) and a height equal to 13.4 feet.

The Longitudinal Strength Analysis shall include stillwater bending moment and shear in accordance with Section 2.3.5 of Reference (2G) as required for all vessels whose length equals 400 feet. or more. Calculations are to be carried out for all anticipated load conditions.

The analysis shall include wave induced bending moment and shear. Wave induced bending moment and shear force distribution in accordance with Section 3-2-1/3.5 of Reference (2E)

shall be applied. The wave length applied shall be equal to the Rules vessel length variable, L (L = 0.96 × LBP). Due to the fact that Vessels of this Contract are not subject to the rules for unrestricted service (ocean), a design wave height of 13.4 ft. is to be used based on the extreme wave height for a ten (10) year return period (49 knot wind, 2 minute average) in the Vessel's operating environment.

Vehicle Deck Structure Analysis - In addition to standard ABS design head calculations, the Lower Vehicle Deck plating shall be designed to withstand rolling and stowed vehicle loads as discussed in ABS Rules Section 3-2-3/5.17. The intent of this requirement is to minimize plate dishing over the sixty (60) year service life.

The Lower Vehicle Deck between casings shall be designed to accommodate semi-trailer trucks, cars, and light trucks. The Lower Vehicle Deck outboard of the casings shall be designed to accommodate only cars and light trucks. Consideration shall be given to vehicles parked in close proximity to each other, resulting in combined concentrated wheel loadings. Deflections of supporting members shall be minimized within normal limits. Stresses shall not exceed the limits provided in ABS Rules Section 3-2-7, Table 2.

The design car and light truck load for the Vessel shall be based upon vehicles weighing 300 pounds per foot of length, distributed on four (4) individual 32 psi tires. A vehicle length of 18'-5" (see the *Vehicle Decks Layout* Subsection in Section 1B of the Technical Specification) shall be used for determining maximum concentrated tire loads.

The design semi-truck trailer load for the Vessel shall be based upon vehicles weighing 813 pounds per foot of length, distributed on eight (8) double tire sets. A trailer length of 45'-0" shall be used for determining maximum concentrated tire loads. Framing support design shall be based upon these loads. For ***plating design***, the minimum double tire load shall be 16,000 lbs. on an area 26 inches wide × 12 inches long. Design shall consider adjacent vehicle loads.

The structural analysis of the Vehicle Deck shall include:

1. Verification for local scantling strength determined using expected vehicle wheel loads and tire footprints per Section 3-2-3/5.17 of Reference (2E).

2. Scantling sizing for vehicle deck and supporting structure in accordance with Section 3-2-3 of Reference (2E) for plating, Section 3-2-7 of Reference (2E) for beams and Section 3-2-8 of Reference (2E) for pillars, girders and transverses.

Verification of Vehicle Deck structural strength using worst case longitudinal strength, superstructure racking and modal vibration conditions included in the Vessel global structural analysis.

Bow & Stern Structure Analysis - Where Vessel Ends feature large flare angles, slamming pressures shall be calculated using the approach outlined for container ships in Section 5-5-3/11.3.3 of Reference (2E) for assessing longitudinal strength and local scantling strength in slamming zones. However slamming pressures shall be calculated using highest

average values of 2,000 psf. A tapered load shall be applied to the slamming zones with a maximum pressure of 2,500 psf at the intersection of the sponson and hull decreasing to 1,500 psf at the outboard sheer guard. Allowable stresses of 36 ksi may be used in sizing local structure due to slamming loads. Slamming zones shall be determined and approved by the WSF Representative for this analysis to specifically target those areas of high slamming frequency which verify both local slamming zone and hull girder section modulus strength.

2.25 PHASE III DETAIL DESIGN AND CONSTRUCTION REQUIREMENTS

Foundation Load and Stress Calculations shall be provided for each large machinery item listed in the *FOUNDATIONS AND BOLT-DOWN FITTINGS* Subsection of this Technical Specification.

The following drawings, in addition to others required by Section 100 of the Technical Specification and the Authoritative Agencies, shall be provided during the Phase III Detail Design stage of Work in accordance with the requirements of Section 100 of the Technical Specification.

A. Book of Construction Standards and Details
B. Scantling Calculations
C. Rudder Design Report
D. Rudder and Rudder Horn Calculations
E. Foundation Calculations

The ***Scantling Calculations*** shall be reviewed by ABS for compliance with class requirements.

(END OF SECTION)